# American POTATO JOURNAL

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## CONTENTS

Potato Foliage Development—*R. A. Kelly, J. B. Adams and P. H. Baird* ..... 29

Leafroll of Potatoes as a Storage Problem—*A. A. Soliman* ..... 35

Protein Content and Specific Gravity of Red McClure Potatoes Increased by 2,4-D Treatment—*Merle G. Payne, Jess L. Fults, Ruth J. Hay and Clark H. Livingston* ..... 46

Description of the "Manota" Variety of Potato—*E. T. Andersen and N. Sandar* ..... 50

Cooking Quality of Potatoes: Its Evaluation and Relationship to Potato Characteristics—*Mary E. Kirkpatrick* ..... 52

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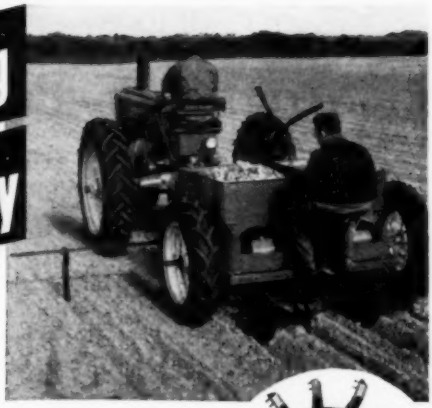

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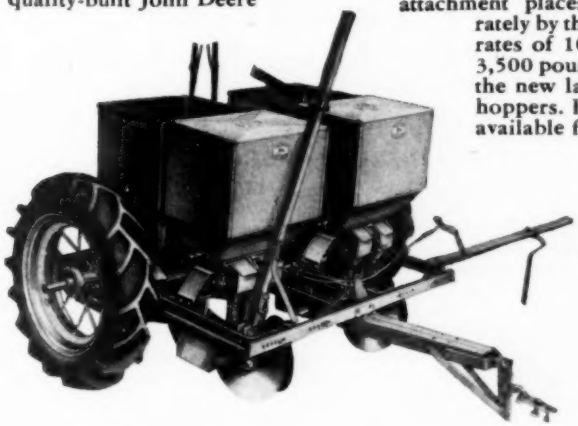

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# POTATO FOLIAGE DEVELOPMENT[1]

R. A. KELLEY[2], J. B. ADAMS[3], P. H. BAIRD[4]

## INTRODUCTION

In 1950, Adams and Kelley (1), working on the field control of potato insects, noted that although nearly 100 per cent reduction of aphid populations could be obtained, the expected elimination of leaf roll did not follow. They suggested that the continued spread of the virus might be associated with aphid feeding that could occur between DDT sprays at a time when the potato foliage was developing so rapidly that unsprayed areas were constantly appearing in all plots.

In order to investigate the daily amount of foliage development during the spray season the present experiment was undertaken.

## REVIEW OF THE LITERATURE

Although Artschwager (2) gave careful attention to the general development of the potato plant, he made little reference to the actual rate of growth. He described the complexity of cellular development in detail without relating it in any way to a time scale. In Australia, Bald (3, 4, 5) examined potato growth in connection with the spread of virus diseases, and showed the rate at which leaf area increased. Contrary to normal field practice, he did not hill the experimental plots. This may have influenced the rate of growth somewhat. Baten and Muncie (6), Davis (7), Gregory (8), Marshall (9), Stanley (10), Stone (11), and Withrow (12) examined possible techniques for the measurement of plant growth. The methods of all these investigators except Stone are either too complicated or expensive to be useful at the present time under field conditions in New Brunswick. Using a planimeter, Stone measured the development of Green Mountain foliage under field and greenhouse conditions. She found that the curve expressing leaflet or entire-leaf growth conformed to the typical curve expressing the rate and distribution of growth in any of the other plant organs, such as stem or root. Measurements, in all instances, were made until the time of flowering.

Stanley stated that, since the total area of the leaves to be treated with insecticides may become 5 to 10 times more than the ground acreage as the season advances, the amounts of chemical to be applied should be based, in part, on the plant surface area per acre of ground.

## METHODS

Investigations were begun in the field at Woodstock in 1950 and continued at Lincoln, N. B., in 1951. By means of daily, replicated

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photographs, measurements of height and width were made. The date of crop emergence in 1950 was June 30.

In 1951, in addition to the photographic record, certain portions of the plant were measured manually. These measurements, in sixty-fourths of an inch, made daily from the emergence of the potato plants on July 4 until senescence, were as follows: (a) the internodal distances on the main stem from base to apex; (b) the stem thickness just above the union of each leaf and the main stalk; (c) the greatest width of the plant when the branches were extended horizontally.

Plants for these studies were selected at random from plantings of Katahdin Foundation seed. All the plots were planted by machine, and cultural practices were those of the commercial field.

## Results

*Rate of Increase in Height:* Increases in height of 19 plants in 1951, computed from the lengths of the internodes, are shown in figure 1. Maximum daily increases occurred during a seven-day period beginning July 30, or mostly during the fifth week after emergence. Daily increases over this period averaged $^{7}/_{10}$ inch.

*Rate of Increase in Width:* Figure 2 shows the daily and weekly increases in width. The greatest increases occurred on August 2 and 3, or during the fifth week after emergence. Daily increases at this time were approximately $^{8}/_{10}$ of an inch.

*Rate of Increase in Stem Thickness:* Figure 3 shows that major increases occurred during the latter half of July and the first three days of August. After this period, the rate decreased rapidly and levelled off approximately August 13. The greatest daily growth occurred during the fourth week after emergence.

*Daily Increases, Height x Width:* From the manual measurements figure 4 gives the results of the daily and average weekly rates of increase in height and width during 1951. It shows that, in this area of New Brunswick, potato foliage developed most rapidly during the fifth week after crop emergence. After the fifth week, rates of increase diminished, although a lesser growth peak occurred on August 22.

*Weekly Increases, Height x Width:* From the measurements by photographs, figure 5 shows the products of the average weekly rates of increase in height and width in 1950 and 1951. In 1950 the greatest increase occurred during the fifth week after emergence; in 1951, during the fourth.

## Discussion

The acceleration of growth of potato plants about the fifth week after emergence is obviously important in a spray program. If further investigation confirms that generally the greatest development occurs about this time regardless of variety, or provides a simple phenologic means of determining when it occurs, spray programs can be adjusted more suitably to the rate of plant growth. In the past, chemical control recommendations have involved almost arbitrary spray intervals — intervals dictated usually by the insect only, not on the basis of the growth of the plant. The authors contend that, to be effective, sprays must be

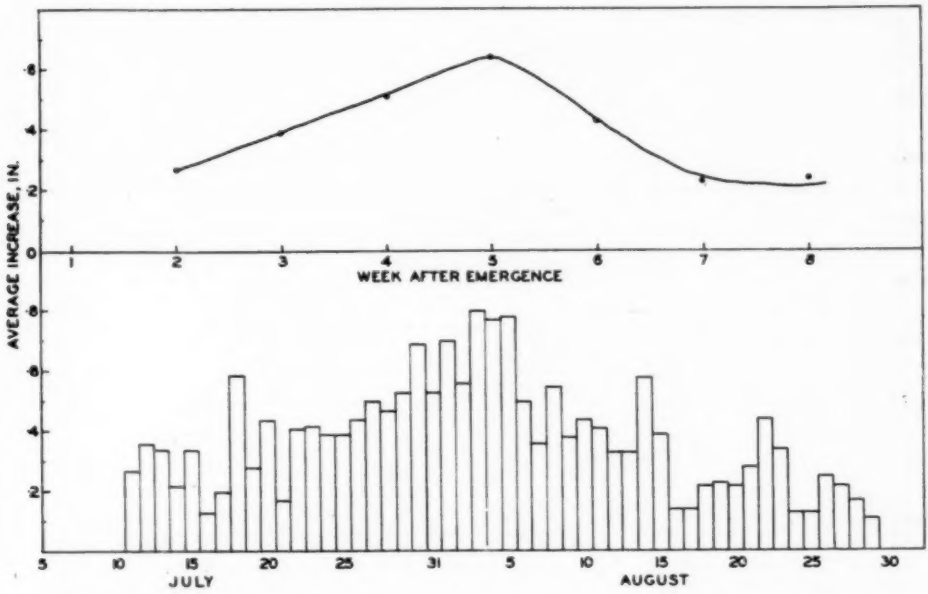


Fig. 1.—Average daily and weekly increases in height of 19 Katahdin plants selected at random from an experimental plot at Lincoln, N. B., 1951. Date of emergence, July 4. (Manual measurements)

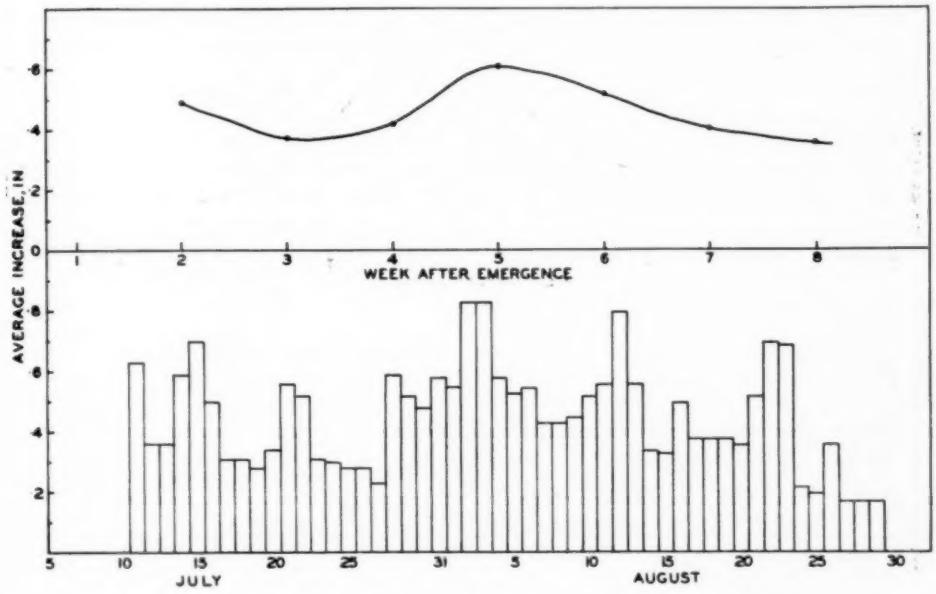


Fig. 2.—Average daily and weekly increases in greatest width of plants in figure 1.

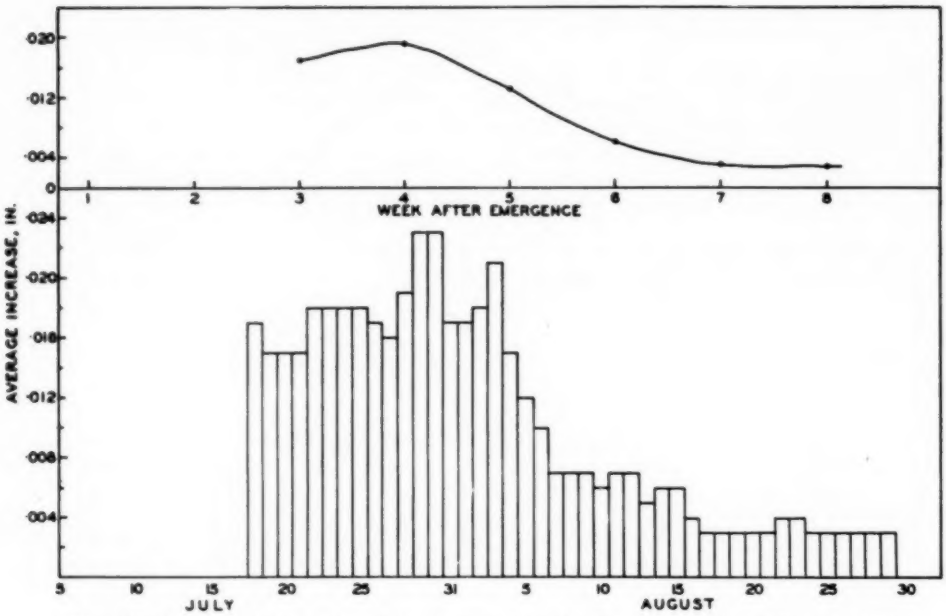


Fig. 3.—Average daily and weekly increases in thickness of main stalks of plants in figure 1.

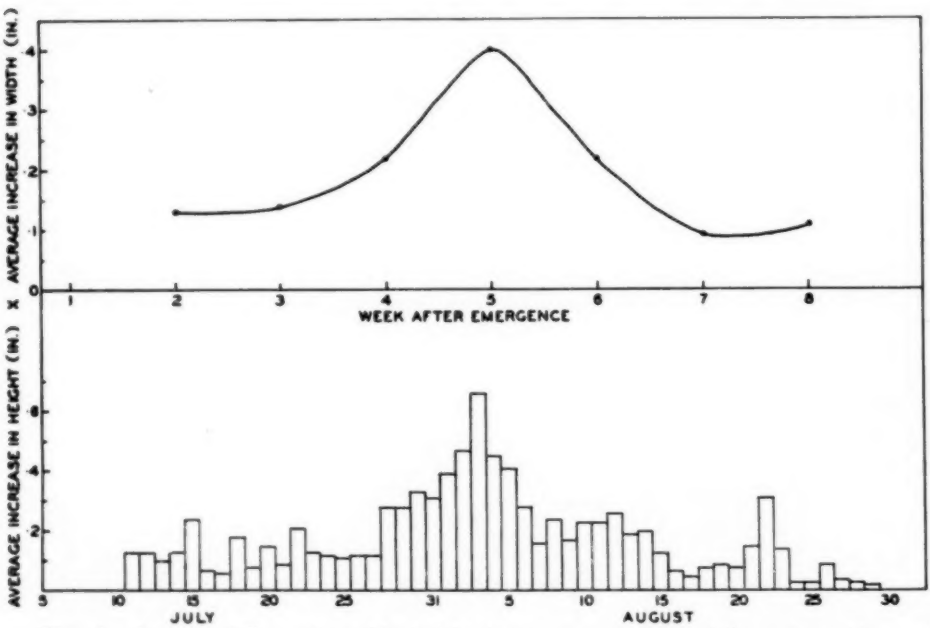


Fig. 4.—Average daily and weekly height increases x average daily and weekly width increases of plants in figure 1.

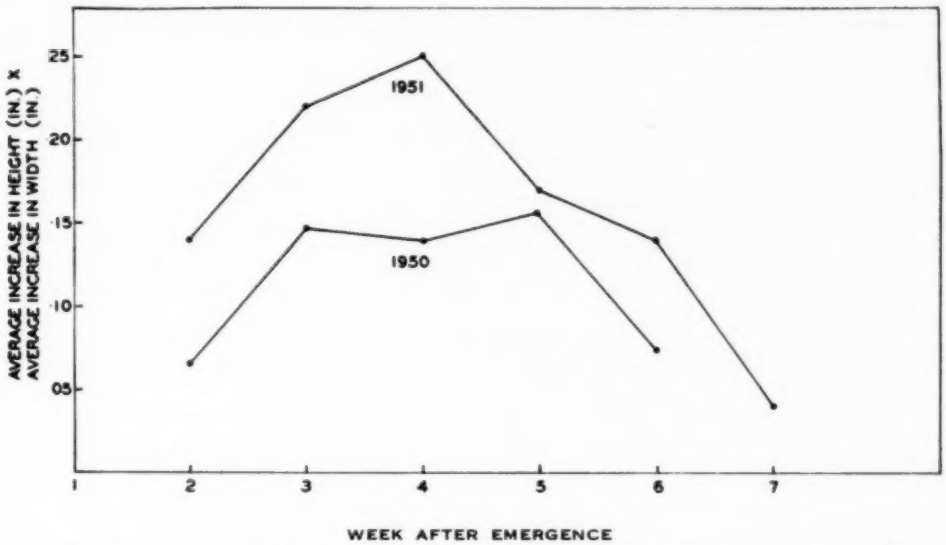


Fig. 5.—Average weekly height increases x average weekly width increases of four Katahdin plants selected at random in 1950 from experimental plot at Woodstock and in 1951 from Lincoln, N. B. Plants emerged in 1950 on June 30 and in 1951 on July 4. (Photographic measurements)

applied at intervals based not only on the presence and susceptibility of the insect concerned but also on the rate of plant development.

## Summary

In 1951 in studies in New Brunswick, increases in the height and width of potato plants were greatest during the fifth week after emergence. The average daily increase at this time was approximately $^{7}/_{10}$ inches in height and $^{8}/_{10}$ in width.

The thickness of the main stalk increased most rapidly from July 28 to August 3, or during the latter part of the fourth week after emergence. After this the rate of increase dropped rapidly, levelling off about August 13.

The products of increases in height and in width show that the rate of development of the potato was greatest during the fourth or fifth week after plant emergence.

The products of photographic measurements of height and width of plants show that, in 1950 and 1951, greatest growth occurred during the fifth and fourth weeks, respectively, after plant emergence.

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# LEAFROLL OF POTATOES AS A STORAGE PROBLEM[1]

A. A. SOLIMAN[2]

The spread of leafroll virus in storage has become an important problem in recent years in many parts of the United States of America, including Minnesota. Tuber samples obtained from warehouses, to which the green peach aphid, *Myzus persicae* Sulzer, has found its way during storage, proved in most cases to be harboring the disease. It is rare that stored lots of potatoes will be one hundred per cent leafroll-free. Aphids finding their way to the sprouts of stored tubers will therefore find no difficulty in transmitting the virus and spreading it. Even the certified potatoes, free from virus, may become infested in storage if the viruliferous aphids gain their way into the storage bins.

This problem heretofore received but little attention, yet it is of considerable importance to the potato growing industry. The present investigations were made with the hope of finding a successful means of at least partial control of the virus disease by restricting its spread during storage of seed potatoes.

General Considerations:

On several occasions it was noticed that seed potatoes from fields that have passed field inspections may, on planting, produce leafrolled plants. This phenomenon may be attributed to either one of two reasons: one is the occurrence of the infection in the field so late in the season that not enough time was given for the symptoms to show up on the vines before harvesting, and the other is the possibility of viruliferous aphids finding their way to the tubers in storage and feeding on their sprouts causing initial infection, or helping to spread the virus under the conditions prevailing in storage. Although both factors play an important role, the latter postulation is supported by the fact that aphids have been recorded frequently on potato sprouts in storage bins. The efficiency of aphids in the spread of the virus disease under storage conditions has been recently illustrated by Granovsky (1949).

The possibility of occurrence of leafroll infection through the sprouts was first demonstrated by Schultz and Folsom (1921). The translocation of the virus through the tuber tissues from one infected eye to another greatly aggravates the problem. Murphy (1923) incriminated *Myzus persicae* Sulzer as the common vector of the leafroll virus of potatoes.

Although these and other authors agree on the ability of aphids to carry leafroll infection from diseased to healthy sprouts during storage, the factors governing the magnitude of infection have not been studied before. It has been pointed out before by some authors that infection may occur at different percentages, without giving an explanation for such phenomenon. The present work was devoted to the study of certain factors which were thought to be of importance in this connection.

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### Determination of Percentage of Leafroll Infection in Storage Due to Feeding of Aphids in Different Densities

Viruliferous aphids, *Myzus persicae* Sulzer, were transferred to the sprouts of two lots of a hundred each indexed and virus-free tubers (Green Mountain) in storage. In one lot only one tuber, infested with twenty viruliferous aphids was placed among the rest of the virus-free indexed tubers in the lot. The whole lot was then placed in storage. In the other lot of the hundred virus-free indexed tubers 500 viruliferous aphids were transferred, and this lot of tubers was also kept in storage. The conditions under which these tubers were stored approximated the usual commercial storage of potatoes. The tubers were kept for one month at a temperature of approximately 45°F. After this storage period the tubers of both lots were sprayed with tetraethyl pyrophosphate (TEPP) to kill the aphids on them. The tubers were then planted in the greenhouse. The percentage of infected plants in each lot was determined by symptoms and by using plant indicators. This was found to be 63 per cent in the case of the light aphid infestation and 98 in the case of the heavy infestation.

Such a difference in the number of infected plants may be attributed to the difference in density of aphids on sprouts in both cases, since no chance was given for the spread of the virus from plant to plant under greenhouse conditions, for plants were sprayed with TEPP regularly at weekly intervals. This simple test indicates the seriousness of aphid spread of the leafroll virus in storage, and the results approximate the results obtained by Granovsky (1949).

### Effect of Feeding of Viruliferous Aphids in Different Densities for Various Time Intervals on the Leafroll Virus Transmission

Indexed virus-free sprouting potato tubers were placed separately in a paper sack. These tubers were arranged into different sets of twelve tubers per set. In one set of sacks a single viruliferous aphid, *Myzus persicae* Sulz., per tuber was transferred. In other sets five, twenty and fifty aphids per tuber were transferred. Aphids in the same instar were used in this experiment so as to have approximately the same biological potential.

Each set of tubers, receiving a given treatment as to the number of vectors used, was divided into four groups of three tubers each. Aphids were allowed to feed in one group of three tubers for twenty four hours. In another group aphid infestation extended to five days; in a third, fifteen days; and in a fourth, for thirty days. On subsequent planting in the greenhouse each tuber was cut into two pieces resulting in six pieces per variant. The results obtained under greenhouse conditions are presented in table 1, illustrating the transmission of leafroll virus to potato tubers, governed by the difference in number of vectors per tuber and the length of time the viruliferous aphids fed on the tuber sprouts in storage.

From table 1 it is obvious that a single viruliferous aphid was able to transmit the leafroll virus within one day (24 hours), feeding on sprouts of healthy potato tubers. The infection probably occurs within a few hours from the time of transferring the insects to the court of infection.

TABLE 1.—*Potato leafroll transmission by Myzus persicae Sulz., considering the density of aphid population and the length of time of feeding.*

| Time of Feeding in Days | Number of Aphids at the Beginning | Number of Seed Pieces (Each Tuber Cut into 2) | Number of Infected Plants |
|---|---|---|---|
| 1 | 1 | 6 | 2 |
| 1 | 5 | 6 | 2 |
| 1 | 20 | 6 | 6 |
| 1 | 50 | 6 | 6 |
| 5 | 1 | 6 | 2 |
| 5 | 5 | 6 | 2 |
| 5 | 20 | 6 | 3 |
| 5 | 50 | 6 | 6 |
| 15 | 1 | 6 | 4 |
| 15 | 5 | 6 | 4 |
| 15 | 20 | 6 | 6 |
| 15 | 50 | 6 | 6 |
| 30 | 1 | 6 | 6 |
| 30 | 5 | 6 | 6 |
| 30 | 20 | 6 | 6 |
| 30 | 50 | 6 | 6 |

It is of interest to determine how much time an insect requires to pick up the virus from an infected sprouting tuber, source of infection in storage and to transmit it to a susceptible healthy tuber through feeding on the sprouts of the latter. A device for microscopic observation may be of considerable value in helping to determine the actual time which has to be spent by an aphid in the actual feeding on the healthy sprouts in order to infect the tuber. Such work was carried on with other viruses and similar investigations would be of value in connection with the spread of the potato leafroll virus in storage.

It was noted that in each case where the number of infected plants was less than six, which was the original number of planted seed pieces used in each set, the infected plants came from separate tubers. Thus in the cases where only two plants showed the symptoms, only certain pieces of two tubers out of the three, used in a given treatment, were infected. Similarly where three plants appeared infected, it is indicated that certain parts of all the three tubers cut into six pieces, as used in the experiment, became infected with the virus. The appearance of the infection at one end of the tuber and its failure to show symptoms at the

other end may be caused by several factors. Among such reasons suspected to have more pronounced effect than others is the fact that the virus may not have time enough to be translocated from the end of the tuber at which the insect or insects have been feeding during the infestation period to the other end of the tuber. This point called for the necessity of running a separate experiment to determine the approximate rate at which the translocation of the leafroll virus takes place through the tuber tissue.

In some cases the failure of transmission may be caused by the presence of biological races among aphids, and it is possible that some individuals are quite efficient in the transmission of given viruses whereas others may not be so adapted. Another possibility is that certain individual aphids used in experiments of short duration may have remained without feeding, or for some reason failed to pick up the virus from an infected source, or if they did, they failed to transmit the virus to the sprouts of healthy ones. All such factors might have had an effect on the results arrived at in these experiments.

Although it is quite obvious that periods for which the aphids have been allowed to feed on the sprouts are comparatively very short when compared with the regular storage periods, yet the results obtained throw considerable light on the economic and biological importance of aphids in the spreading of leafroll virus, if they by chance find their way to the stores of potatoes at the sprouting period.

The large number of aphids was used in the initial inoculation of a single tuber, mainly for an academic interest, since such a heavy infestation is unlikely under normal storage conditions. However, in many cases tubers from commercial storage bins were found to be infested with hundreds of aphids of different developmental stages per tuber.

## Translocation of the Leafroll Virus in the Tuber

In connection with the studies of the leafroll transmission in storage it was found of prime importance to detect the reasons why the problem may often be of more serious proportion than one may at first realize. As noticed in the previous experiment, there might be a possibility that the virus inoculated at one tuber end may pass to another. However, such a postulation may not necessarily be true under the conditions of the previous experiment for the simple reason that even in cases of inoculation of a tuber by a single aphid, the insect may crawl from one eye to another during its course of feeding and thus bring about the infection of more than one eye. Despite the fact that aphids are more or less sedentary during their feeding, and once they settle to feed, they will remain feeding in one position unless disturbed or overcrowded, it was of interest to determine whether or not the virus itself travels from the site of inoculation to other parts within the tuber in storage or through propagation. With this idea in mind the following experiment was carried out.

Two sets of 30 indexed tubers were used in this investigation. Inoculation with viruliferous aphids was carried out at different tuber ends. Of the 60 tubers involved in this work, 20 tubers were inoculated at the stem end, 20 at the bud end, and a third group of 20 tubers was

inoculated at both ends. For this purpose the tubers were covered by cheese cloth except the part to be inoculated. Each tuber was then enclosed in a small paper sack, exposing only the end or ends to be inoculated. After infesting with viruliferous aphids, the tubers were left for fifteen days to make sure that the vectors had enough time to transmit the virus. Each tuber was inoculated by, at the least, five active aphids in approximately the third nymphal stage. Tubers thus treated were divided into two lots after the infection period was over. The tubers of one lot were planted in four-inch pots without being cut, the end or ends which were inoculated being marked. The tubers of the other lot were similarly planted after each had been cut across into two seed pieces and the inoculated end or ends appropriately marked.

When examined, all the plants from tubers treated in the above experiment were found to be infected with leafroll (Figure 1).

These observations indicate that the virus was able to pass from the inoculated end of the tuber to the other end, which was not inoculated in the present experiment. (Figure 2).

The symptoms expressed in these leafrolled plants, developed from originally non-inoculated eyes, were equal in severity to those that appeared on the plants which developed from the inoculated eyes. Furthermore, those plants that resulted from planting two twin seed pieces showed about the same symptoms in their severity as those appearing on plants that developed at the two ends of tubers planted without being cut. These results are not in agreement with those arrived at by Stewart and Glasgow (1930). These authors stated as a result of their observations that when the tubers were inoculated at one end, the other eyes away from the inoculated ones, when tested for the presence of the virus, proved to be free of it, thus concluding that the virus is incapable of movement from one eye to another through the potato tissue. It may be a question of the time allowed to elapse after the inoculation before detecting the appearance of the virus at any site away from the court of inoculation that has resulted in the differences between the results arrived at in the present work and those recorded by the above-mentioned authors. The period of fifteen days allowed in this investigation seems to have been sufficient for the virus to move from one end of the tuber to the other. Until the time when the nature of the physiological activities of the virus within the tuber tissue is studied at different intervals after inoculation, the phenomenon of translocation of the virus within such tissues under storage conditions cannot be thoroughly understood. It is therefore of value to determine the time necessary for the virus to pass through a definite area of the potato tuber tissue. Such information can be obtained by testing tubers receiving a similar treatment to that described above, and examining tubers by proper tests at regular intervals, starting approximately from a few minutes or hours after inoculation and extending to 15 days. The present experiment, however, definitely showed that from practical consideration a relatively short time of only 15 days is sufficient to translocate the leafroll virus throughout the entire tuber under storage conditions.

## Aphid Control in Storage

Because of the various handling processes through which the potato

Figure 1.—The two plants in each pot developed from different ends of the same tuber. In each case the plant on the right is the one that developed from the inoculated end of the tuber, whereas the one on the left is the development of the non-inoculated tuber end. Both plants in each pot show leafroll symptoms.

Figure 2.—The plants from the same tuber infected at the bud end. The plant on the left developed from the bud end, infected in this experiment. The one on the right developed from the stem end, the non-infected end, of the same tuber. Both plants show leafroll symptoms.

tubers pass before they go into storage, it is believed that a very few individual aphids are able to find their way into storage with the potatoes. Some, however, may. If some of them could do so, the aphids would have a chance to survive and to increase during storage. They would have some difficulty in the early part of the storage period to establish themselves. This is simply due to the lack of favorable food, since potato aphids are known to prefer feeding on green parts of plants or on soft tissues such as the newly developing buds in potato eyes. It was of interest to study this problem under controlled conditions, and experiments were conducted to find out whether or not aphids can feed directly on the tuber tissues. Although aphids prefer to feed on growing potato tissues, they can however pierce the corky tuber layers. As a rule they try to reach the phloem tissue but they also can obtain enough food without doing so. They may accumulate in the eyes of tubers, where they feed on very small dormant buds. The factors which usually restrict aphids in their feeding to the phloem tissue on the green vines are known to be the preferred pH concentration of the phloem sap and the nutritional value of the food the aphids seek. It is possible that these requirements are met with by other tuber tissues including those outer cell layers. Although there is a very poor chance for aphids to go into storage with the tubers at the time of harvest, however, if they do so, they can survive throughout the storage season and can build up in great numbers on the new sprouts toward spring. Aphids also can be brought into storage on sacks, clothing, tools, and the like. The vegetable storing bins are not completely aphid-free and may serve as a source of aphid infestation. On the whole, aphids can get into storage at the beginning of the storage season and have a chance of surviving until the time of tuber sprouting.

The utmost attention is to be given to prevent the infestation that may occur at harvest time and through the storage period until the tubers begin to sprout. The infestation and building up of population may take place through (a) the increase in population of aphids that has accompanied the tubers from the beginning of the harvest in storage process, and (b) outside contamination during storage by any one of a number of various animate or inanimate agents.

Whatever the way by which aphids may reach the stored tubers, they have to be prevented from increasing, if any appreciable control of the spread of leafroll virus or other virus diseases is contemplated. No such control is to be expected without checking the aphid infestation or eliminating those present even in few numbers. The need for this control becomes very obvious when we consider the results of the present experiments, which indicate that a single viruliferous aphid can infect a tuber after feeding on it for a comparatively short time, and that infection passes easily from one eye of a tuber to another, and that aphids can easily spread from tuber to tuber in storage. The source of infection during storage might be the infected aphids or the diseased tubers present within the stored lot.

The problem calls for vigilant control measures to be carried on under storage conditions. The present studies have shown that the time passed by a potato tuber lot in storage in the presence of numerically known aphid infestation determines the extent of infection within the lot of stored tubers. This proved to be an evidence of infection directly related

to the population size of the aphids. The aphid population increase is a phenomenon governed by the biotic potential of the species on the background of ecological conditions prevailing during the storage period.

A limited scale experimental tests were organized by using suitable insecticides for possible control of aphids under storage of potatoes.

Two lots of 100 healthy, certified, sprouting tubers were infested with 20 aphids per lot in the late nymphal and adult apterous stages. One of the lots was then sprayed with TEPP (tetra ethyl pyrophosphate) at a concentration of 3 cc. per gallon of water, five days after the infestation by aphids. The other lot was left without spraying. Both lots were kept in storage for one month, during which period a second application of the insecticide was given to the first lot. Tubers from both lots were planted in the greenhouse. Leafroll readings on the plants showed that the number of infected plants in the treated lot was far less than that of the untreated lot. On a percentage basis the sprayed plants showed 8 per cent infection whereas the untreated ones showed 50 per cent infection. It is of interest to note that a short time of five days of aphid feeding resulted in 8 per cent infection. Additional experiments are planned for the future to determine the effect of the insecticide treatment of the stored potato tuber lots at different periods from the time of harvesting and transferring aphids to the tubers. Granovsky (1949) showed that, under commercial natural storing conditions, the percentage of infection in some instances was as high as 87 per cent.

Such an insecticide treatment may not be convenient to use under regular commercial conditions because of the fact that either sacks or loose potatoes are usually stored in bins in high piles, and the possibility of getting the spray particles on the tubers beyond a limited thickness of a layer is doubtful. Even aresol bombs, which furnish very fine particles, hardly can be used conveniently to overcome this practical difficulty. A suitable method can be developed and this point needs to be considered in practice on a commercial scale.

Tetra ethyl pyrophosphate, at the concentration used, proved to be harmless to the sprouts. One hundred per cent growth was obtained after several applications of that insecticide without any deformation of the plants. The rapid disintegration of the insecticide, added to its high efficiency in aphid control, makes it suitable for use not only in the experimental studies, but possible in practical treatment of tubers before storage, especially if they are known to be aphid infected. However, its practicability under commercial potato storage conditions is doubtful.

## Recommendations for the Control of Leafroll in Storage

Under storage conditions, the aphids usually have a good opportunity to transmit and spread the leafroll virus, provided that they can find their way to the stored tubers and especially while the latter are sprouting. The practical method of leafroll control under these circumstances is at least partially possible by several measures: (a) To avoid premature sprouting of the potato tubers during storage periods. New developments in this field of sprout inhibitors are now in progress. A recent report on such a procedure is that published by Marth and Schultz (1950), and others. However, no matter what practical precautions will be taken in

that direction, sprouting to various degrees may take place under certain conditions and aphids will breed on sprouts. The problem is more complicated because the aphids are able to feed directly on the tuber tissues. b) To avoid aphid infestation during storage. The most effective means of controlling infestation in storage is to keep aphids from reaching the tubers, and by cool storage to prevent the insects from building up to any sizable population if they happen to find their way to the stored potato tubers.

Once potatoes become infested, there is no other alternative than using an aphicidal insecticide that can be effective against aphids no matter how impracticable such a measure may be. The certified seed potatoes may warrant the use of insecticides. As appeared from the results of the experiments, the application of TEPP on the tubers is considered efficient as far as aphid control is concerned. Before the crop is dug, potato hills could be treated with aphicidal spray to prevent aphids from going into storage with the tubers. This treatment possibly could be used on the tubers, if practicable, in a washing process before storage. The sacks, tools, and also the bins should be treated with insecticides even if they do not obviously show infestation.

Samples of the stored tubers should be selected at random and studied to find out if they harbor aphids. Such sampling should be made from time to time throughout the storage period and particularly during the sprouting time, if the latter occurs. If aphids prove to be present on the tubers in any numbers, an insecticidal application should be made at once, preferably with a suitable aphidical dust. No chances should be taken on the assumption that the aphid population may not be high enough to cause considerable damage. Any delay in treatment gives a chance for the aphids to increase and the spread of the virus. Taking into consideration the rapidity with which aphids reproduce, one should realize how risky it is to delay the application of the perfect control measure.

Since the aphids can move from one tuber to another or be shaken on other tubers in a process of handling, and since the virus can move within the tuber tissue from one end to the other in a relatively short time, it is far better to plant small whole tubers than to cut seed pieces, in order to avoid the spread of certain virus diseases. By planting whole tubers instead of the cut seed pieces, the number of infected plants likely to appear in the field will be cut down considerably. Besides reducing the number of infected plants to a minimum, planting whole tubers makes the process of roguing easier and more efficient.

In summary the recommendations to be followed for the control of the leafroll virus of potatoes are as follows:

1. Keep the growing potatoes in the field free from leafroll by using certified seed and by destroying diseased plants periodically.
2. Control of the aphids in the field with suitable aphicidal spray or dust.
3. Keep the storage bins clean and free from aphids and from vegetables of any kind before potatoes are brought in and during their storage.
4. Avoid the use of aphid-contaminated articles in handling potatoes during the harvest and in storage.

5. Give insecticidal treatments to storage bins before storing potatoes, and treat sacks and other articles if needed.
6. Avoid any means of contamination during storage.
7. Test samples of the stored tubers for the presence of aphids at different intervals during the storage period, and apply an aphicidal —preferably dry— treatment at once in case of the appearance of infestation.
8. Keep potatoes in cool storage to avoid sprouting and to prevent aphid breeding.
9. Use sprout inhibitors.
10. Use whole tubers in planting.

## Summary

The percentage of infection of potato tubers in storage was shown to be directly correlated with the density of aphid population feeding under storage conditions. An increase in the number of aphids was followed by an increase in the percentage of infection of tubers.

The present study experimentally proved the translocation of the virus within the tuber tissues, opposing previous concepts of other investigators concerning this important matter. The virus was able to pass from one eye at either end of the tuber to the other end within fifteen days.

Recommendations for the control of the leafroll virus under storage conditions are also suggested in outline form.

## Acknowledgments

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# PROTEIN CONTENT AND SPECIFIC GRAVITY OF RED McCLURE POTATOES INCREASED BY 2,4-D TREATMENT[1]

MERLE G. PAYNE, JESS L. FULTS, RUTH J. HAY AND CLARK H. LIVINGSTON[2]

In recent years, it has been shown that it is possible to increase the vitamin C content (13) and to intensify the red skin color of Red McClure potatoes, without a depression in yield, by treating plants prior to harvest with small amounts of the sodium salt of 2,4-D (6). When treated tubers were desprouted and planted, there were no significant differences in stems, number of stems per plant, or yield (10). Treatment resulted in an increase of free glutamic acid and a decrease of eleven other amino acids (8), but no change in the nitrate content (5) was observed.

Steward and Caplan (16) have shown that 2,4-D stimulates protein synthesis of isolated potato tissue. Corns (3) has recently indicated that 2,4-D treatment influences the protein content of bean plants. He has shown that 2,4-D increases the protein in the stems, but with few exceptions decreases the protein in the leaves. The response appears to be conditioned by soil moisture at, and following, the time of treatment. Other workers who have found increased protein content in plant stems and roots of plants treated with a growth regulating chemical include Sell *et al* (14), working with red kidney beans, Borthwick (1) with tomato plants, Smith *et al* (15), with bindweed, and Rasmussen (12), with dandelion roots. Northen (7) has indicated that auxins may condition a dissociation of cellular proteins as evidenced by decreases in the structural viscosity of the protoplasm of treated bean stems and petioles. He has further indicated that the resulting dissociated proteins may be reassociated into labile and native proteins of modified pattern.

Prince and Blood (11) reported that the butyl ester of 2,4-D used in the proper amounts on growing plants increased the specific gravity of Irish Cobbler, Green Mountain, Sebago, Houma, Chippewa and Katahdin varieties of potato. According to Clark *et al* (2) there is a high degree of relationship between specific gravity and starch content in the potato. High starch content is one of the characteristics which determines "mealiness," a desirable cooking quality. Therefore, treatment which results in higher specific gravity of potatoes should produce a product of higher quality, other factors remaining equal.

The purpose of this paper is:

(1) to report the changes in the amount of potato protein, caused by the treatment of Red McClure potato plants with 2,4-D.

(2) to report the corresponding changes in specific gravity.

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## METHODS

The Red McClure potatoes used were selected from plants sprayed with ½ pound per acre of the sodium salt of 2,4-D at the early bloom stage. Representative control samples were also used. All samples were randomly selected from half-acre plots. The potatoes were grown at the San Luis Valley Experimental and Demonstration Farm near Monte Vista, Colorado, in 1951. All plots were sprayed with DDT for psyllid control. Samples were stored at 40°F., in slatted oak crates, in the potato cellar of the horticulture department of Colorado A. and M. College.

In December, 20 lots of five potatoes each were put into polyethylene bags, sealed, and frozen. One-half of these were control potatoes, the other one-half were treated. In January, five lots of treated and five lots of control potatoes were allowed to thaw. The potatoes were then washed and dried. Twenty-five milliliters of juice, squeezed from all five tubers in a lot, were added to 95 per cent ethanol until the final alcohol concentration was 80 per cent. The treated samples were handled similarly. The solutions were allowed to boil one minute; then cooled, and the proteins filtered out. The proteins were filtered into dried and weighed Gooch crucibles and heated to 100°C. for three hours or until they reached constant weight. The ideal temperature for heating protein for weighing is 70°C. It was thought that the higher temperature of 100°C. might have caused protein decomposition, thus check samples were lyophylized.

Check samples were run simultaneously using the lyophylizer according to the following procedure: 75 mls. of juice from each of the lots used in the preceding method were squeezed into 95 per cent ethanol until the final alcohol concentration was 80 per cent. The supernatant liquid was decanted and the protein precipitate was then placed in flasks. The excess alcohol was removed under vacuum. The remaining protein precipitate was brought to dryness with the lyophylizer. After lyophylization, the dry solids were weighed and placed in a desiccator. The two above-mentioned methods were repeated in February.

Eighty per cent alcohol, in addition to precipitating proteins, also precipitates soluble pectins. Therefore, quantitative determinations for soluble pectins were performed according to the method of Freeman (4).

In the lyophylized protein, there was no appreciable difference between the soluble pectin in the treated and untreated samples. There may have been some change in the insoluble pectins of the potatoes, but since our method of protein determination involved only the soluble pectins, the insoluble pectins were not determined. Therefore, any dissimilarities observed in the weights of the precipitate were due to differences in protein and not to differences in pectin.

Specific gravity was determined for every potato in the treated and untreated samples.

## RESULTS

The data in table 1 show the effect of 2,4-D treatment on the protein and specific gravity of Red McClure potatoes. At both dates of sampling the specific gravity and protein content of the treated tubers were significantly greater than the controls. The treated tubers showed mean specific gravities of 1.099 and 1.084 compared with 1.074 for the controls.

Likewise, in the treated samples the mean protein content was 22.3 mg/ml of juice, 26.0 mg/ml of juice, as compared with 20.0 mg/ml of juice and 18.2 mg/ml for the untreated tubers.

TABLE 1.—*Protein and specific gravity changes in Red McClure potatoes due to 2,4-D treatment.*

| Dates | | Treated | Untreated | Difference | Minimum Difference Required for Significance | |
|---|---|---|---|---|---|---|
| | | | | | .05 | .01 |
| Jan. | Specific Gravity | 1.099 | 1.074 | + .025 | .011 | .015 |
| Feb. | Specific Gravity | 1.084 | 1.074 | + .010 | .005 | .008 |
| Jan. | Protein[1] | 22.3 | 20.0 | +2.3 | 1.4 | 2.0 |
| Feb. | Protein | 26.0 | 18.2 | +7.8 | 4.0 | 6.0 |

[1]The unit of measurement was milligrams of protein per milliliter of juice.

## DISCUSSION

As indicated in an earlier paper by the authors, (9) this investigation has substantiated our preliminary findings that 2,4-D treatment of Red McClure potato plants prior to harvest increases significantly the protein content of the tubers. The average protein increase for both sampling dates was 27.2 per cent.

The fact that 2,4-D treatment of plants in the field increased the protein content of the tubers is in accord with the report of Steward and Caplin (16) who found that 2,4-D stimulates protein synthesis of isolated potato tissue.

The increase of protein following 2,4-D treatment may be a mechanism involved as the plant adjusts its metabolism to the 2,4-D. If indoleacetic acid is part of an enzyme system in which the protein combines with it, the addition of 2,4-D would cause it to enter the enzyme complex, thus hindering the ability of the protein to function properly.

The results of this study substantiate those reported by Prince and Blood (11) in 1949, *i.e.* proper 2,4-D treatment of growing plants produces tubers of higher specific gravity and hence better quality than untreated controls.

## SUMMARY

Treatment of growing Red McClure potato plants with 2,4-D at a rate of one-half pound per acre produces tubers with significantly higher protein content and with a significantly higher specific gravity.

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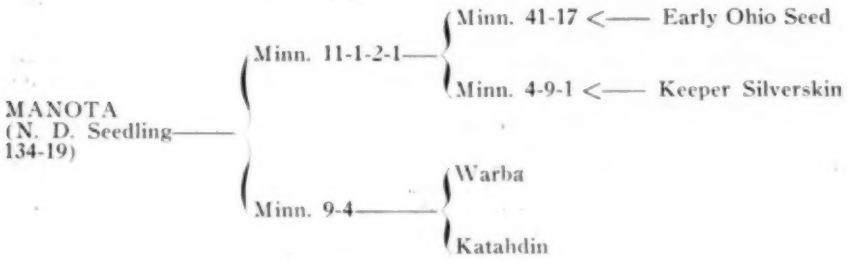
# DESCRIPTION OF THE "MANOTA" VARIETY OF POTATO[1]

E. T. ANDERSEN[2] AND N. SANDAR[3]

## Origin

Manota is a selection from a cross made at Park River, North Dakota, in 1938. It was received for trial at the University of Manitoba in 1945 and included in adaptability trials in Manitoba since that time. In that same year it was dropped from the North Dakota trials. Its original North Dakota selection number was 134-19.




## Description

*Plants*—large, spreading at maturity.
*Stems*—thick, upright, green in color, 4 to 7 per plant, slightly hollow, very slight pubescence.
*Nodes*—slightly swollen, green.
*Internodes*—green.
*Wings*—green, slightly waxed.
*Stipules*—medium, green, few hairs.
*Leaves*—uniformly spaced along stem, long, green, slightly drooping.
*Midribs*—green, scantily hairy.
*Primary leaflets*—lanceolate grading to oval, some joined leaflets, medium size, 3 to 4 pairs, slight hairiness.
*Petioles*—green.
*Secondary leaflets*—near base of petioles of the primary leaflets, not always evenly paired.
*Tertiary leaflets*—small.
*Inflorescence*—axillary, much branching.
*Leafy bracts*—few.
*Peduncles*—long, green, very scantily hairy.
*Pedicels*—long, green, slightly hairy.

*Flowers:*

Calyx lobes—tips long, green, hairy.
Corolla—medium, white.
Anthers—orange yellow.
Pollen—abundant, highly fertile.
Style—straight.
Stigma—bilobed, green.

*Tubers:*

Shape—oblong; index based on 120 tubers of the 1951 crop was as follows: index of width to length 82.81; of thickness to width 78.72; of thickness to length 64.72.

Size—generally medium size — on the same 120 tubers of the 1951 crop the mean length was 3.43", mean width 2.82", and mean thickness 2.22".

Skin—smooth, self-colored, creamy white.

Eyes—very shallow, same color as skin.

Eyebrows—curved, inconspicuous in many cases.

Flesh—very white.

Sprouts—creamy white when developed in the dark.

Maturity—midseason in Manitoba, very comparable with Irish Cobbler.

Pathological Characteristics.

*Virus diseases*—shows symptoms of leaf roll or mild mosaic very distinctly when infected.

*Net Necrosis*—no evidence found to date.

*Late Blight*—susceptible.

*Scab*—susceptible.

*Bacterial Ring Rot*—susceptible.

*Hollow Heart*—occurs rarely; incidence very low during the 6 years when grown in Manitoba. Irish Cobbler grown in the same plots at times had prohibitive amounts of hollow heart tubers.

Cooking Quality

The cooking quality of Manota has been rated good to excellent in all tests. Its raw flesh is very white and remains so after cooking. Tests for rate of boiling, baking and frying are satisfactory, resulting in a very pleasing and appealing flavor. It has rated well for baking, having a sufficiently high starch content, and also an oblong slightly flattened shape, which is in its favor for this method of cooking.

Remarks

Manota is of medium maturity, white skinned with good cooking and storing qualities. It is fast growing, has good yielding ability producing an average of 6 - 8 tubers per hill, a high percentage of which are marketable. Tubers are formed close to the stem and are detached very easily at harvest. The well shaped tubers and very shallow eyes leave little to be desired for market preference. Keeping and storage quality are very good, comparable with Irish Cobbler.

Manota was discarded in North Dakota in 1945, possibly because of virus infection. It was retained at the University of Manitoba and appeared promising in all trials in Manitoba.

The Manota variety of potato was licensed for sale in Canada in 1952, and is now eligible for certification.

In Manitoba, most of the commercial production of potatoes centers on the heavy soils of the Red River Valley. The Pontiac variety is the only one which shows any particular adaptability but it is late in maturity and has poor cooking qualities. Two midseason varieties, Irish Cobbler

and Canus, are grown extensively but both of these have serious faults. This emphasizes the growers' needs for an adaptable variety of midseason maturity. The following table shows that Manota has demonstrated both good adaptability and performance on several soil types in Manitoba.

*Comparative yield of marketable tubers and percentage starch of Manota, Irish Cobbler and Warba potato varieties produced over a period of 6 years at seven different locations in the Province of Manitoba.*

| Variety | Yields in Marketable Bushels per Acre | Per cent Starch |
|---|---|---|
| Manota | 323.5 | 15.37 |
| I. Cobbler | 308.1 | 15.41 |
| Warba | 304.1 | 14.75 |

Yield represents the average of 32 replicated yield trials for Manota and Irish Cobbler and 28 for Warba.

[1]Accepted for publication October 21, 1952.

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## ABSTRACT

### COOKING QUALITY OF POTATOES: ITS EVALUATION AND RELATIONSHIP TO POTATO CHARACTERISTICS[1]

MARY E. KIRKPATRICK[2]

Cooking quality in potatoes is understood to refer to characteristics of appearance and taste which potatoes possess when cooked. For best quality it is generally agreed that boiled, mashed, and baked potatoes should be creamy white in color, should have a moderately dry to dry and mealy texture and a good, natural potato flavor. Boiled potatoes should be free from excess sloughing. The effect of storage temperature and time on the cooking quality of potatoes and the relationship of cooking quality to various compositional factors of the potatoes were investigated for two consecutive years. The study was carried on cooperatively by the Bureau of Human Nutrition and Home Economics and the Bureau of Plant Industry, Soils and Agricultural Engineering. Six varieties each obtained from three locations in the late crop-producing areas were studied, except that samples of one variety came from only two locations so that there were 17 lots in all.

The average specific gravity of each lot of potatoes was determined soon after harvest. The brine flotation method was used to select samples of average specific gravity for cooking tests and chemical analyses.

Cooking tests were carefully controlled and followed routinely. A trained judging panel scored the palatability factors color, sloughing, mealiness, dryness and flavor on a 3 to 1 scale. The panel was trained to judge objectively, ruling out prejudice or bias or personal preferences.

Average specific gravity of the 17 lots studied differed from one lot to another. In 1948 the range was 1.067 to 1.096; in 1949 it was 1.065 to 1.098.

Flavor scores of boiled, mashed, and baked potatoes showed little correlation with sugar content in samples cooked at harvest and after 3 months storage at 55°F. In these cases, all sugar contents were below 2 per cent. Storage at 40°F. at both 3 and 6 month periods resulted in much higher sugar contents (ranging from 5 to 7 per cent) and significant correlations of off-flavor with sugar content were obtained. Off-flavors other than excessive sweetness were also more marked at these two storage periods.

A gradual change in color of the cooked potatoes also occurred during storage. A tendency for yellow and gray color to supplant the white color more common to freshly harvested potatoes was frequently noted.

Sloughing of the cortical layer and disintegration of tubers, of especial importance in boiled potatoes, was highly correlated with specific gravity, total nitrogen and alcohol insoluble solids content. Dryness and mealiness of boiled, mashed, and baked potatoes were also highly correlated with these same compositional factors. Multiple correlations showed that a greater influence was exerted by specific gravity and total nitrogen combined on the palatability factors dryness, mealiness, and sloughing rather than by either compositional factor alone.

Dry matter, starch, and alcohol insoluble solids content were also highly correlated with dryness and mealiness in boiled, mashed, and baked potatoes and sloughing of boiled potatoes. Alcohol insoluble solids and total nitrogen taken together exerted a greater effect on the palatability characteristics than either compositional factor alone.

Results of the two years' work showed some differences in detail yet the trends were consistently the same. Although specific gravity was the identifying factor in the raw potatoes tested which correlated most closely with the kind of cooked product obtained, more research is needed to assist in developing a practical means of classifying potatoes as marketed according to their suitability for the various common methods of cooking them.

[1]Accepted for publication November 17, 1952.

[2]Food Specialist, Bureau of Human Nutrition and Home Economics, United States Department of Agriculture, Washington, D. C.

Abstract of a paper presented at the Annual Meeting of the Potato Association of America at Cornell University, Ithaca, N. Y., September 10, 1952. A full report of this study will be published soon in a U.S.D.A. Bulletin.

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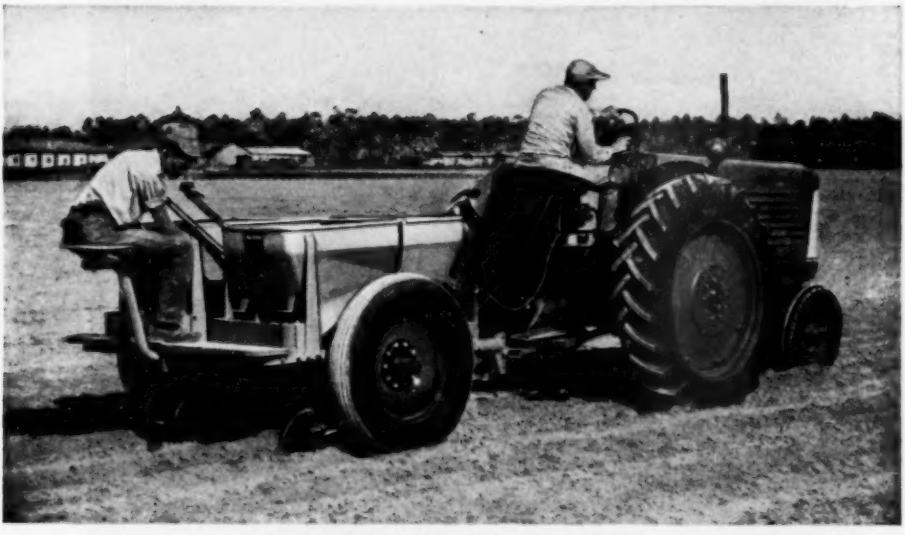

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# American POTATO JOURNAL

***Volume 30*** ***March 1953*** ***Number 3***

## CONTENTS

Host Range of Potato Leafroll Virus—*John J. Natti, Hugh C. Kirkpatrick and A. Frank Ross* ..... 55

Resistance of Some American Potato Varieties to the Late Blight of Potatoes—*L. C. Peterson and W. R. Mills* ..... 65

Relation of Time of Planting Potatoes to Tuber Flea Beetle Attack in Nebraska and Wyoming—*R. L. Wallis* ..... 70

Resistance of Potato Varieties to Charcoal Rot—*M. J. Thirumalachar and Pushkarnath* ..... 73

**Potato News and Reviews**

Announcement ..... 77

Palletized Handling and Storage of Potatoes—*Sam Kennedy* ..... 78

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